Validation of ECG-derived heart rate in cod (*Gadus morhua L.*) with an implantable data logging system

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BACKGROUND

Archival tags have been used on fish for a number of years to measure temperature, pressure and salinity, among other parameters. However heart rate measurements in fish have been difficult to conduct in the wild due lack of commercial availability, large size of the recording systems, restriction in setups with external systems and unreliable measurements or calculations of heart rate. This work presents a validation of a commercial ECG-derived heart rate system on farmed Atlantic cod, both its signal processing algorithm and recording quality.

METHODS

Eight farmed Atlantic cod (W=1742g±373g L=50,7cm±5cm) were implanted (Fig.1a&b) with Star Oddi DST milli-HRT (W=11.8g L=39.5mm W=13mm) heart rate and temperature monitors and kept in captivity for 50 days, measuring heart rate and temperature every 5 minutes (114.357 recordings). In addition, ECG data (Fs=100Hz) used to derive heart rate was recorded every 30 minutes (19.042 recordings).

Heart rate calculations were manually validated for each fish with about 2.500 ECG data snippets (6s) per fish. Baseline measurements were compared with over 30 days of stable temperature (10°C) and standard feeding from one week after implantation, concluding with a stressor experiment 5 weeks later. The stressor experiment was initiated with 3 minutes of chasing the fish, then fish was netted and exposed to air for 1 minute before being returned to the tank.
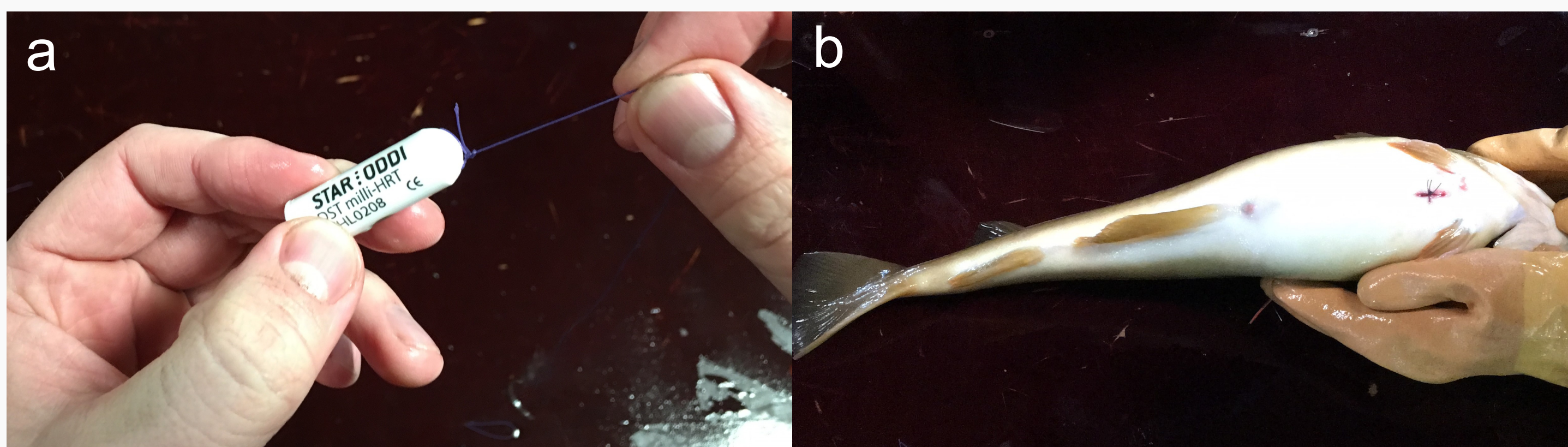

Figure 1. a) Logger is anchored with suture to minimize internal movement of logger and therefore reduction of noise. b) Logger is implanted between pelvic fins, fish is anaesthetized with MS-222.

RESULTS

The eight fish showed both individual periodical variation as well as individual baseline variation of the heart rate during the experimental period, with mean heart rate ranging from 30bpm to 46bpm (Table 1 and Figure 2).

	DST 1	DST 2	DST 3	DST 4	DST 5	DST 6	DST 7	DST 8	MEAN
Manual	39,6	35,5	35,4	40,7	46,1	30,1	44,2	38,7	38,8
All	40,1	35,1	34,6	40,4	46,1	30,6	44,2	39,7	38,9

Table 1: Average HR values for each data storage tag (DST), both manually derived (N=18490) and QI filtered (N=92694).
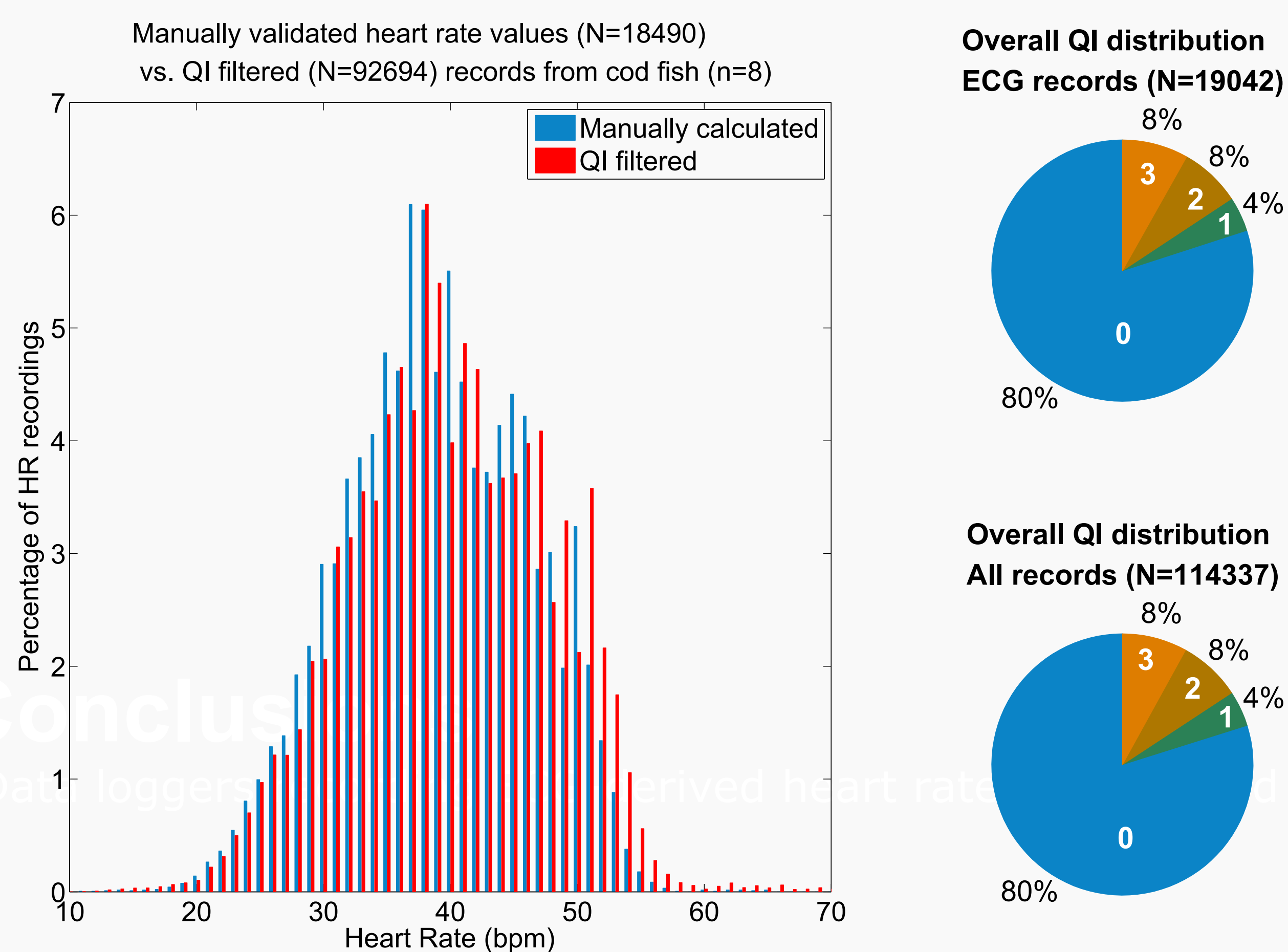

Figure 2. (left) Percentage of occuring Heart rate values, from manually calculated values as well as QI filtered values. (right) Distribution of QI for all ECG records (top) and all recorded data (bottom).

The quality index (QI), which is an algorithmic assigned value of the quality of the ECG (see Figure 3), was used to filter the data set; QI=3 always being eliminated and QI=1 and 2 eliminated in all loggers except two. A total of 21.643 measurements were eliminated (19% of the recorded data). It was possible to manually calculate 18.490 out of 19.042 ECG records (97%). QI distribution can be seen in Figure 2 (right).
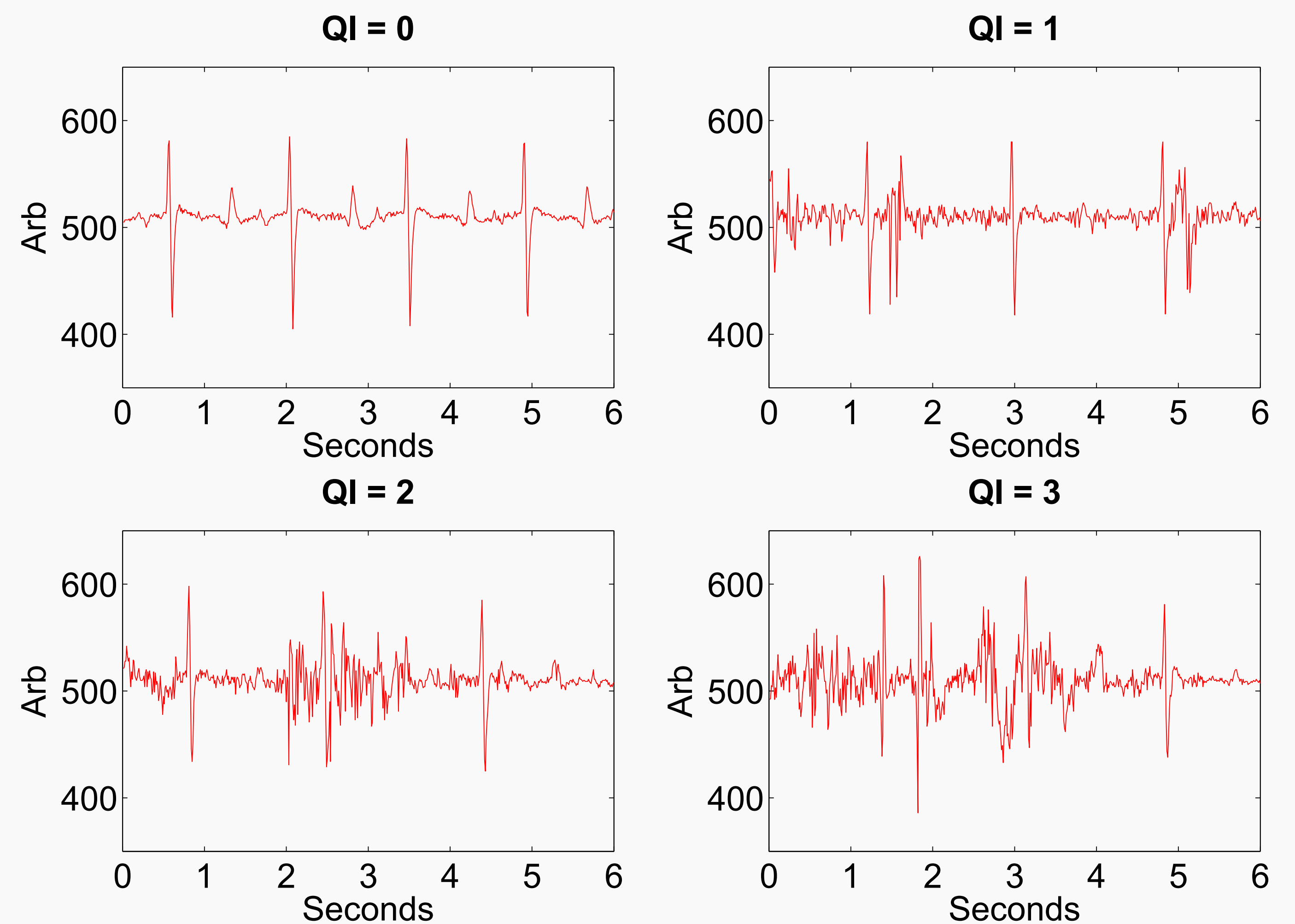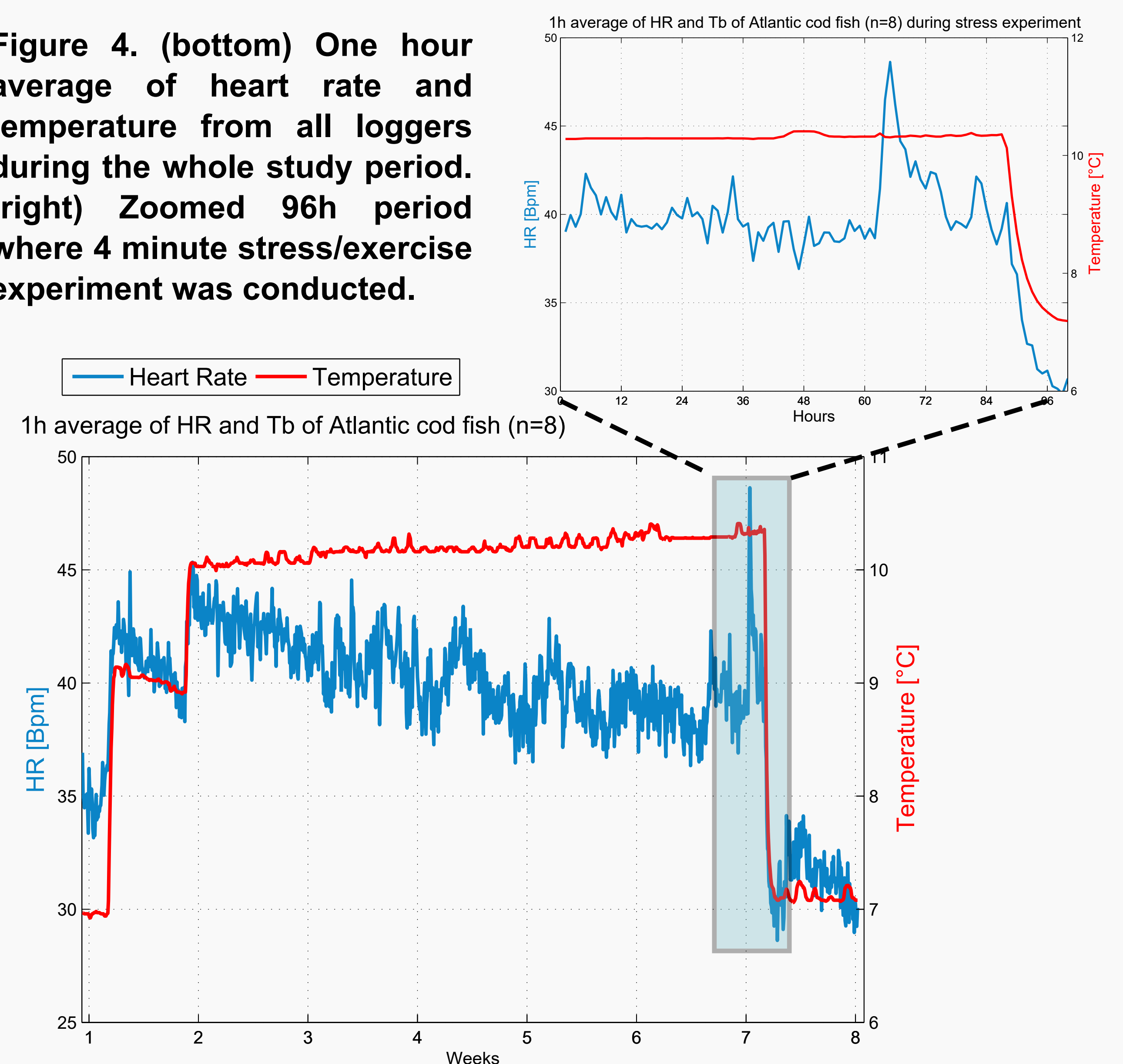

Figure 3. Sample ECG waveform for each of the QI's (0, 1, 2 and 3)

Figure 4. (bottom) One hour average of heart rate and temperature from all loggers during the whole study period. (right) Zoomed 96h period where 4 minute stress/exercise experiment was conducted.

All fish showed an increase of at least 25% from their individual mean heart rate during the stressor experiment and a recovery period of about 4h on average post stressor experiment. All fish showed a strong correlation of heart rate and sea temperature.

CONCLUSIONS

Data loggers recording ECG-derived heart rate can be used to assess cardiac response in Atlantic cod and other types of fish if validated.

Manual calculations of heart rate were possible in 97% of the recordings while using the integrated QI categorization provided 81% of the data eliminating QI = 3 in all and QI = 2,1 in all but two loggers.

Heart rate increased at least 25% in each fish during a 4-minute stress/exercise experiment and remained elevated for about 4h on average.